HERA Beam Tail Shaping by Tune Modulation

C. Montag, BNL

HALO'03

Introduction

HERA:

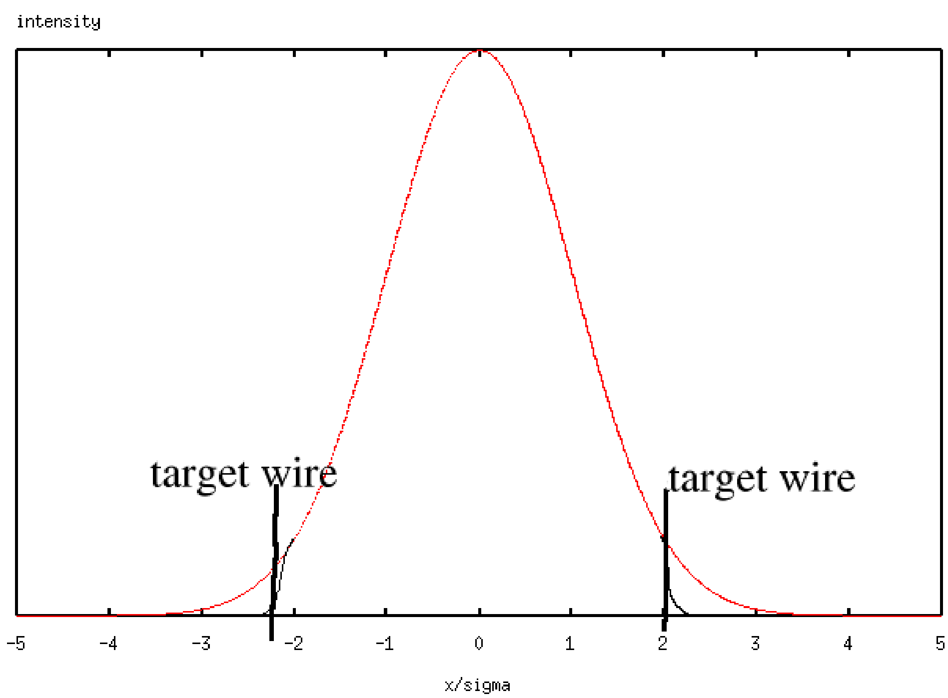
1. 920 GeV protons on 27.5 GeV electrons (positrons)
2. Four experiments:
   - e-p collider experiments ZEUS, H1
   - internal polarized gas target experiment HERMES in the electron ring
   - internal halo target experiment HERA-B in the proton ring
3. Simultaneous operation of all experiments mandatory

At the HERA-B design interaction rate

$$N_{\text{crossing}} = \frac{\dot{N}_{\text{interactions}}}{n_{\text{bunches}} \cdot f_{\text{rev}}} \approx 4 \ldots 5,$$

the diffusion into the beam tails is not sufficient.

To keep the required interaction rate, the wire targets have to move closer to the beam core, creating a "hard edge" of the initial Gaussian distribution:



The hard edge of the transverse proton distribution leads to large interaction rate fluctuations with relative rms deviations

$$\sigma_{\mathrm{rel}} = \frac{\sqrt{\langle(\dot{N}_{\mathrm{interaction}} - \langle\dot{N}_{\mathrm{interaction}}\rangle)^2\rangle}}{\langle\dot{N}_{\mathrm{interaction}}\rangle}$$

of more than 50 percent due to disturbances like beam orbit jitter.

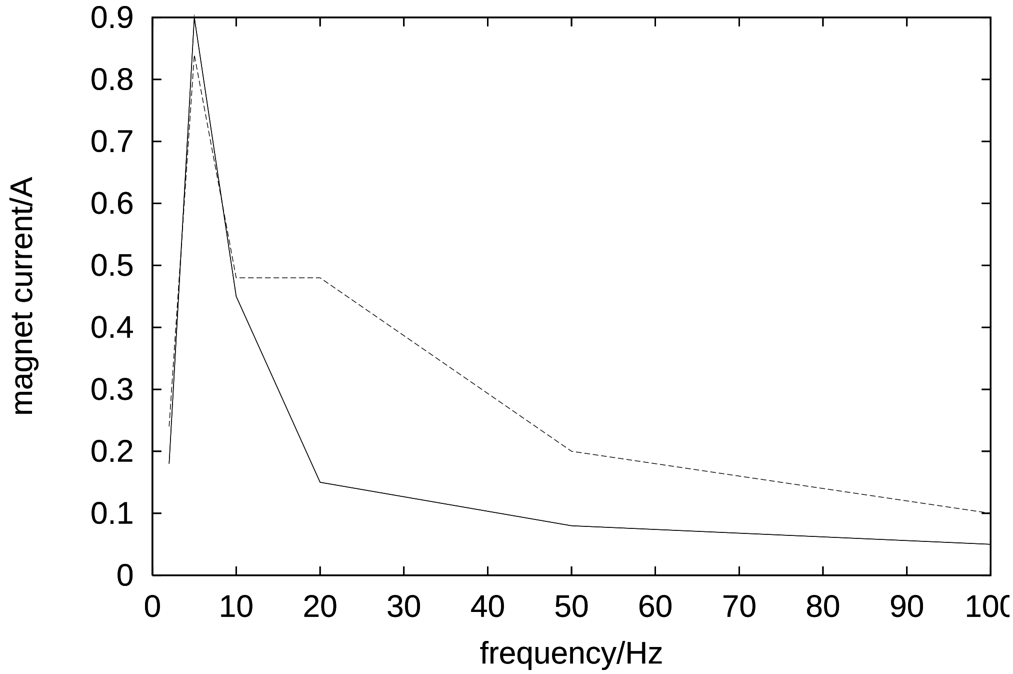
To improve this situation, artificial enhancement of the diffusion into the transverse beam tails without disturbing the core of the beam is required.

Tune modulation together with beam-beam interaction is most promising method.

Set-Up

Power supplies of tuning quads in the quadrant “West” are modified to provide modulation capability.

Measured transfer function:

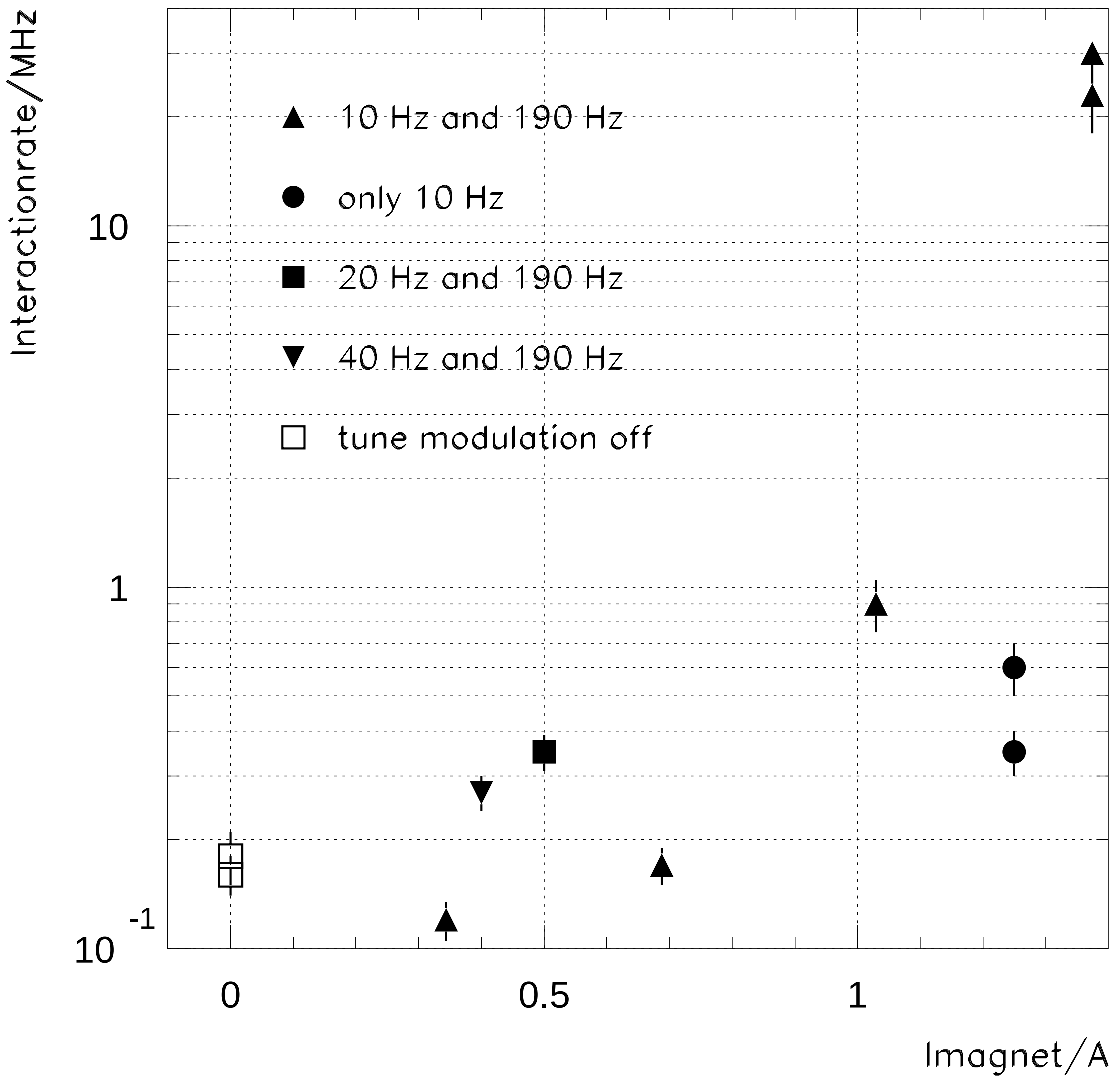


High frequencies are suppressed by the magnets’ inductance, low frequencies by the power supply controllers trying to remove this “jitter.”

Modulation signals are generated by a PC with DATEL PC-420 wave generator board.

Experiments

1. Interaction rate at fixed wire position:
   - Insert wire until 10 MHz interaction rate are reached
   - Retract wire by 100 μm, turn off wire position feedback
   - Observe interaction rate for different tune modulation parameters



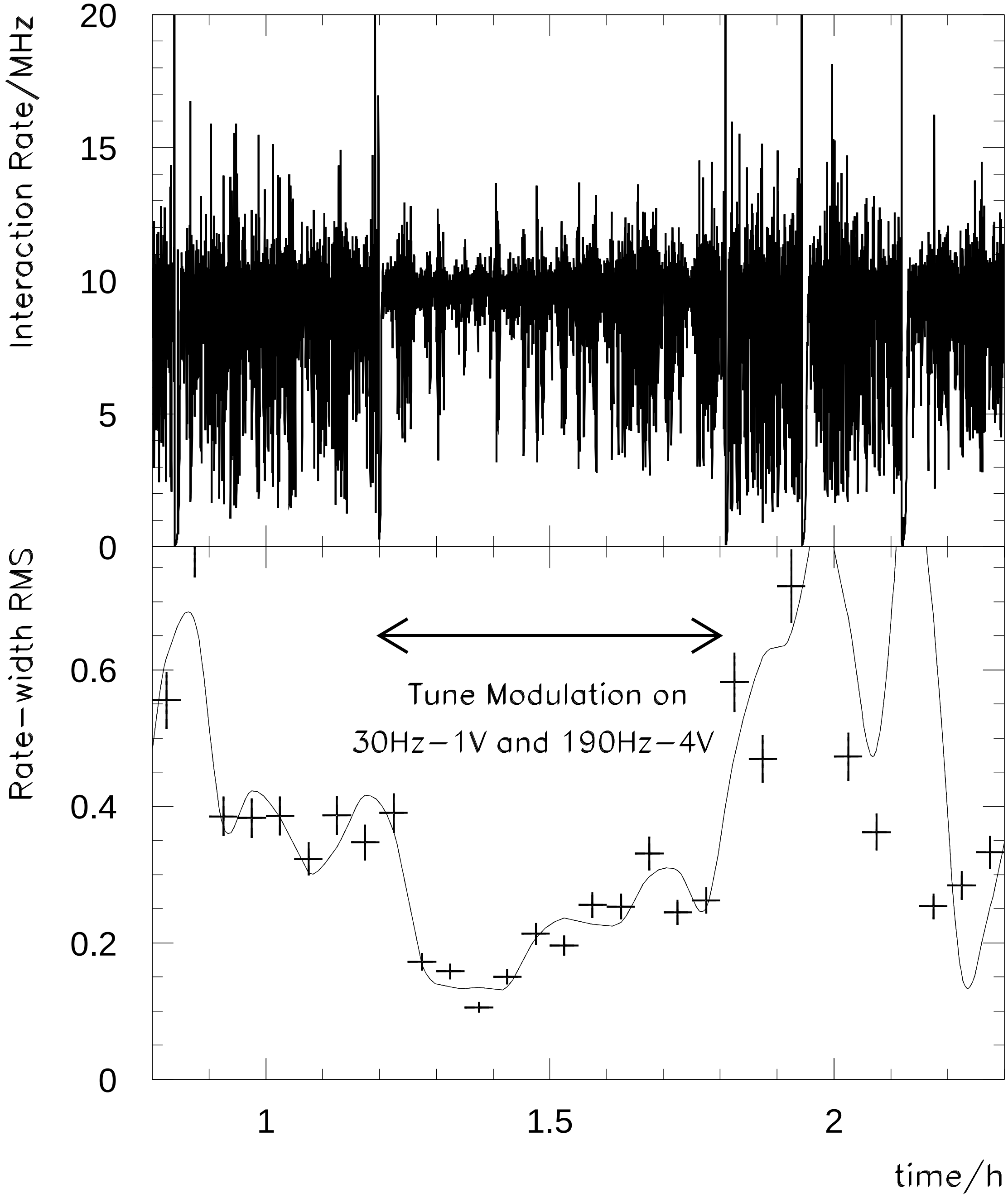
Interaction rates for diferent tune modulation parameters.

2. Observe interaction rate stability with wire position feedback on ($\rightarrow$ regular running conditions):

- Insert wire until 20 MHz interaction rate are reached
- Observe relative rms interaction rate fluctations

  $$\sigma_{\mathrm{rel}} = \frac{\sqrt{\langle(\dot{N}_{\mathrm{interaction}} - \langle\dot{N}_{\mathrm{interaction}}\rangle)^2\rangle}}{\langle\dot{N}_{\mathrm{interaction}}\rangle}$$

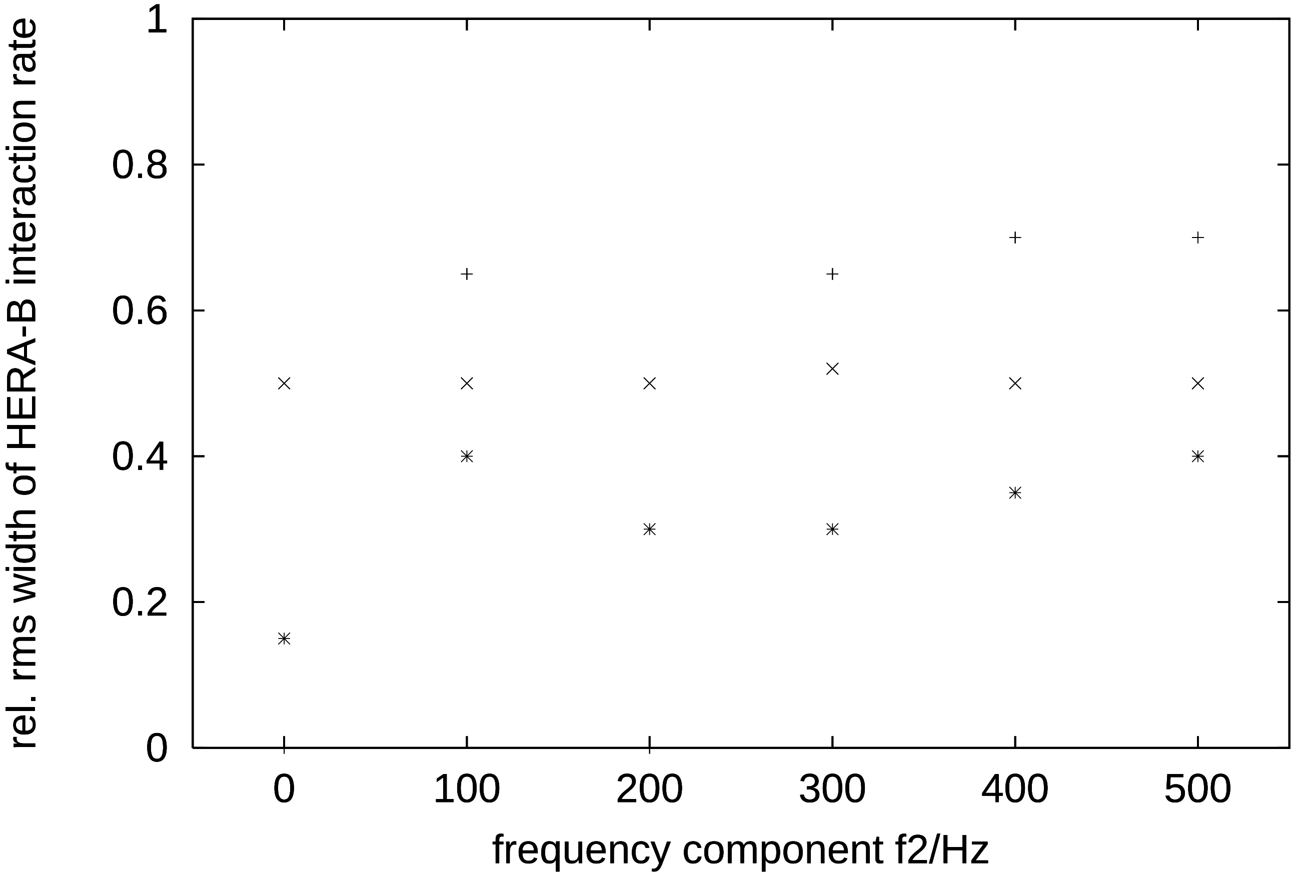
  for different tune modulation parameters



Example of HERA-B interaction rate stabilization by tune modulation.

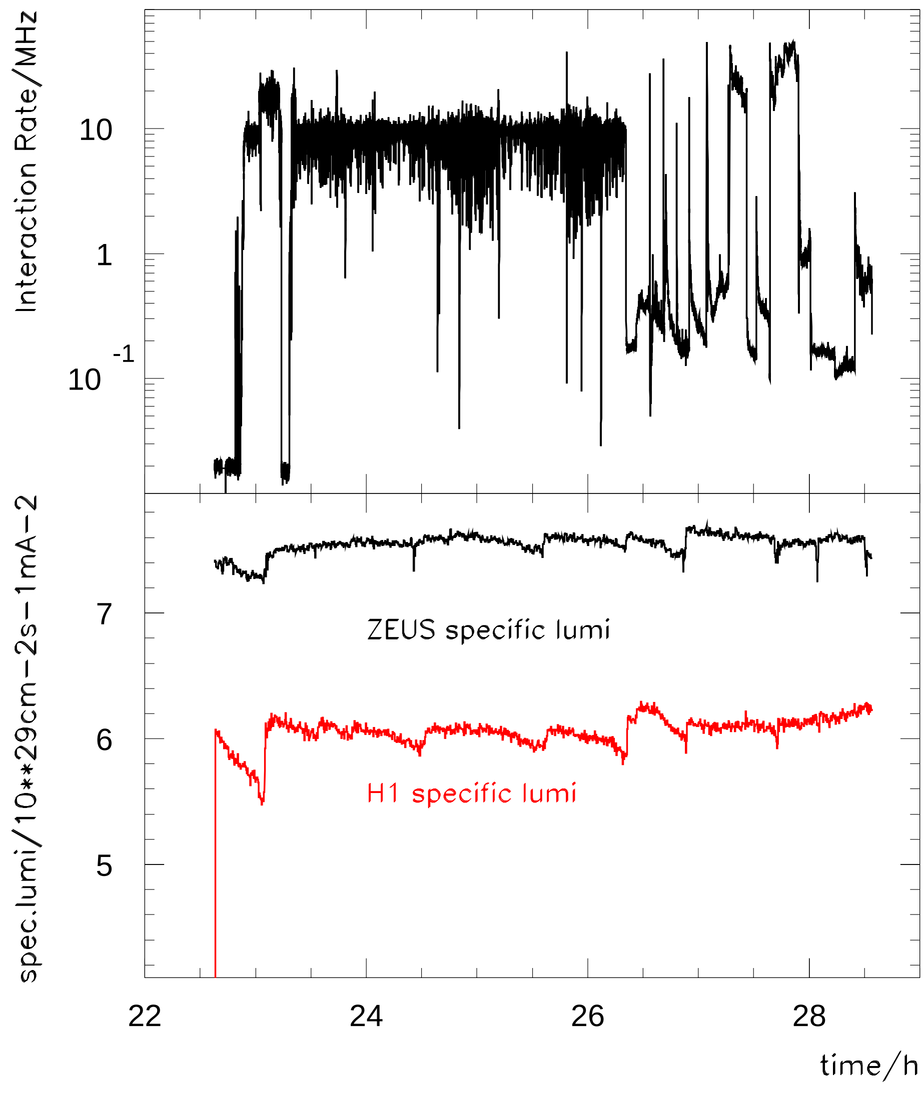
Tune modulation signal:

$$
\begin{aligned}
U(t) &= \sum_i U_i \cdot \sin(2\pi f_i \cdot t), \\
f_1 &= 10\,\mathrm{Hz}, \\
U_1 &= U_2 = 0.5\,\mathrm{V},\ 1.0\,\mathrm{V},\ \text{and}\ 2.0\,\mathrm{V}
\end{aligned}
$$



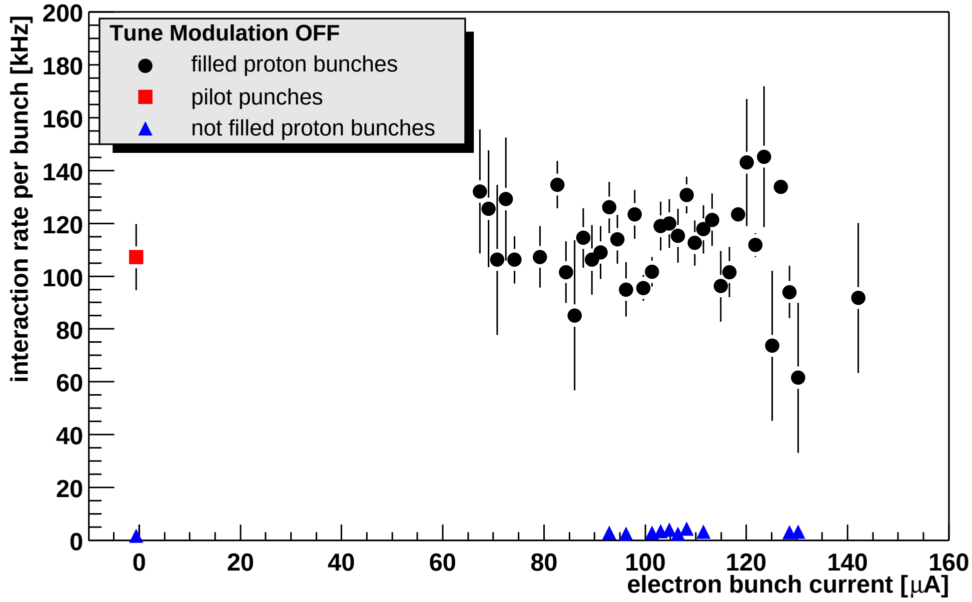
Interaction rate stability as a function of f_2, for three different modulation depths.

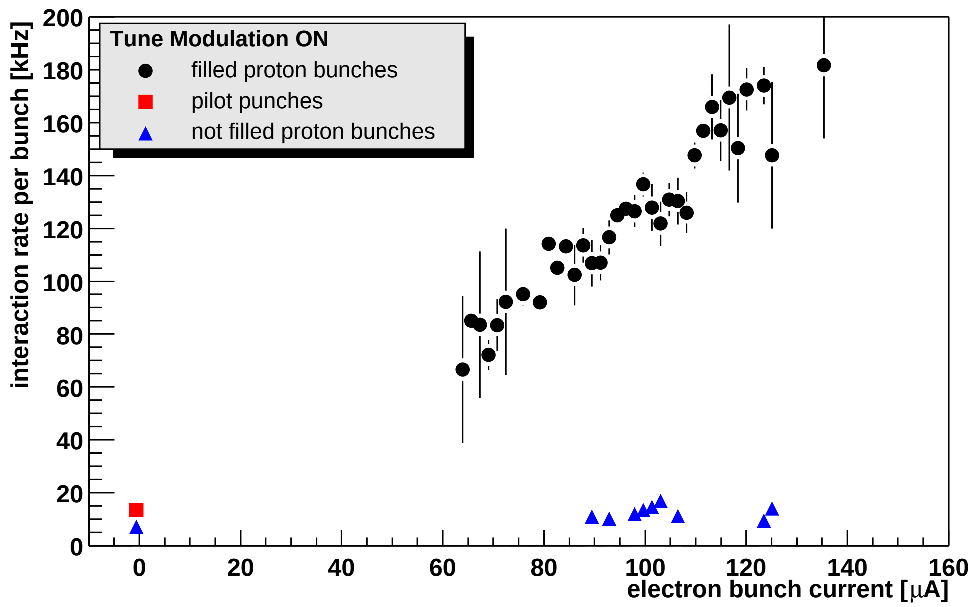
HERA-B interaction rate and specific luminosities at ZEUS and H1 during a regular HERA run with tune modulation on:



- Rate stability clearly improved
- Specific luminosity does not suffer

HERA-B interaction rate per bunch vs. bunch current of the corresponding electron bunch, with and without tune modulation:





Conclusions

- HERA-B interaction rates have been successfully stabilized by tune modulation in combination with beam-beam interaction
- Specific luminosity (beam size of the core) does not deteriorate
- Correlation between single bunch interaction rates and intensity of the corresponding electron bunch shows that stabilization effect is caused by tune modulation together with beam-beam effect, not just due to orbit oscillations caused by off-center orbits in modulated quadrupoles.